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EFFECTS OF INPUT TEMPERATURE AND AIR VOLUME ON MOISTURE REMOVAL FROM SEED COTTON

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EFFECTS OF INPUT TEMPERATURE AND AIR VOLUME ON MOISTURE REMOVAL FROM SEED COTTON

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ABSTRACT

Cottons were tested for all combinations of five input temperatures and two air volumes to determine the effect on moisture removal from seed cotton in the gin drying system. Input temperatures were 150°, 200°, 250°, 300° and 350° F and air volumes were 3,500 and 4,500 cubic feet per minute. Moisture removed from seed cotton in the drying system increased as the mixpoint temperature was increased, regardless of air volume. The temperature drop between the air and cotton mixpoint and all other points in the drying system was greatest at the lowest air volume. Increasing the air-volume to seed-cotton weight ratio from 31.1 to 38.3 cubic feet per minute per pound of cotton had no significant effect on moisture removal from seed cotton. Also, air volume had no effect on the efficiency of the drying system, based on weight of moisture removed from seed cotton per 1,000 cubic feet of air.

INTRODUCTION

The average cost for drying a bale of cotton varies considerably from one gin to another. Some of this variation can be attributed to differences in seed-cotton moisture level and in fuel costs, which cannot be controlled. A large part of the variation can be attributed to inefficient operation of driers, however, and improved drying system efficiency thus offers a potential reduction in ginning costs.

Fans consume approximately two-thirds of the power used in ginning. A large percentage of this power is utilized in conveying cotton through the drying and seed-cotton cleaning systems. Reducing the quantity of air required for conveying and drying seed cotton would permit the use of smaller, less powerful fans, with resulting lower initial costs and reduced power costs.[2] In addition, smaller fans would reduce noise, thus improving working conditions in the gin.

Limited tests were conducted at Agricultural Research Service's former Southeastern Cotton Ginning Research Laboratory, Clemson, S.C., to determine the effects of input temperature and air volume on moisture removal from seed cotton in the drying system. This publication reports data accumulated during the 1971 and 1972 crop years.

EXPERIMENTAL PROCEDURE

The machinery sequence was as follows:

1. Automatic seed-cotton feed control.
2. Standard 24-shelf tower drier.
3. Seven-cylinder cleaner No. 1.
4. Stick and green-leaf machine.
5. Seven-cylinder cleaner No. 2.
6. Extractor-feeder.
7. 79-saw gin.

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[2] Holder, S. H., and McCaskill, O. L. 1963. Costs of electric power and fuel for driers in cotton gins, Arkansas and Missouri. U.S. Dep. Agric., Econ. Res. Serv. [Rep.] ERS-138, 12 pp. Wilmot, C. A., and Watson, H. 1966. Power requirements and costs for high-capacity cotton gins. U.S. Dep. Agric. Mark. Res. Rep. No. 763, 23 pp.

8. Two unit saw-type lint cleaners in tandem.
9. Bale press.

The feed rate was adjusted to achieve a processing rate of four bales per hour for all test lots, thus making the air-to-cotton ratio dependent upon airflow.

The two levels of air volume were 3,500 and 4,500 cubic feet per minute. Air volume was determined immediately before the hot-air and seed-cotton mixpoint, and between the hot-air and seed-cotton mixpoint and the entrance to the tower drier. Air volume was determined at both points before cotton was introduced into the system, but only measured at the first point after cotton was introduced.

The five levels of input temperature were 150°, 200°, 250°, 300°, and 350° F. Input temperatures were measured at the hot-air and seed-cotton mixpoint. Temperatures were measured at each of the following points during processing: (1) immediately before the hot-air and seed-cotton mixpoint, (2) in the transition at the entrance to the tower drier, 25 feet from mixpoint, (3) between shelves 10 and 11 in the tower drier, 82 feet from mixpoint, (4) between shelves 16 and 17 in the tower drier, 116 feet from mixpoint, (5) between shelves 22 and 23 in the tower drier, 150 feet from mixpoint, (6) in the discharge transition below seven-cylinder cleaner No. 1, 218 feet from mixpoint, (7) inside the gin (ambient air), and (8) outside the gin (ambient air). During the second year, temperatures were also measured internally at each side of the drier between shelves 16 and 17 and shelves 22 and 23.

The fuel supply was adjusted to maintain a constant flame at all input temperatures. Because the mixpoint temperature increased after seed cotton was introduced into the system, the fuel supply to the burner was first adjusted to produce the desired temperature when the system was empty, then readjusted to obtain that temperature after cotton was introduced.

Mercury-in-glass thermometers and thermocouples were used in the temperature-measuring system during the first year, the thermocouples employed in conjunction with a recording oscillograph. The thermometers were read immediately prior to the introduction of cotton into the system and at 2-, 4- and 10-minute intervals. Temperature data were obtained from the oscillograph chart at the same time intervals. Because the thermometers responded slowly to temperature change and because reliable values were difficult to obtain from the oscillograph chart, an improved temperature-measuring system was used in the second year. In the improved system, thermocouples were connected through a pushbutton switching unit to a digital thermometer. The operator depressed the desired pushbutton and recorded the value observed on the indicator. The entire measuring sequence required less than 30 seconds, compared with approximately 90 seconds required with the system using mercury-in-glass thermometers. Temperatures were recorded at time intervals identical to those used during the first year.

Cottons were processed on five different dates each season, each processing date serving as a replication. Cotton for each processing date was obtained from the same producer and from the same field to assure homogeneity of source cotton.

Seed-cotton samples were extracted from the wagon and from the feeder apron to determine trash levels before and after seed-cotton drying and cleaning. The fractionation procedure was used to determine trash content.

The oven method was used to determine moisture content of seed cotton and lint. Samples for moisture determination were extracted at the following locations: (1) wagon, (2) entrance to tower drier, (3) exit from tower drier, (4) entrance to seven-cylinder cleaner No. 1, (5) feeder apron, and (6) lint slide. Samples were extracted by hand through sampling ports at the entrance and exit of the tower drier and at the entrance to the seven-cylinder cleaner. Lint samples were also extracted at the lint slide for classification data.

In summary, the test variables were air volume and temperature. Air volume was tested at two levels; temperature, at five levels. There were five replications per year in each of two years. Test variables and test levels were compared through an analysis of variance for a split-plot design combined over years. The main plot factor was air volume. Subplots were the five temperature levels.

RESULTS

Before cotton was introduced into the system, the low and high air volumes averaged 3,600 and 4,400 cubic feet per minute. When cotton was introduced into the system, low air volume decreased 365 cubic feet per minute and high air volume decreased 500 cubic feet per minute (table 1). Although temperatures averaged 7° to 9° above the projected value for each of the temperature levels, good control was achieved at the mixpoint, and differences between levels were uniform. Temperature variations for each level ranged from a low of ±3.2 percent to a high of ±8.8 percent.

Processing rates varied among temperature levels from 100 to 105 pounds of seed cotton per minute, with the rate at 150° F significantly lower than the rates at 200°, 300°, and 350° F (table 2). Since feed-roll speed and the moisture content of seed cotton at the mixpoint were constant for all temperature levels, differences are assumed to be the product of operator technique. Inexperienced telescope operators often feed cotton to the hopper at widely varying rates. Observation has revealed that differences in feed rates occur when the quantity of seed cotton maintained in the hopper above the feed rolls is varied. An increase in the height of seed cotton in the hopper produces an increase in the density of cotton at the feed rollers, which results in a higher feed rate.

The ratio of air volume to seed-cotton weight was 31.1 cubic feet per minute per pound of cotton at the low air volume, significantly lower than the ratio of 38.3 cubic feet per minute per pound at the high air volume. Among temperature levels the ratio ranged from 33.7 to 35.8 cubic feet per minute per pound of cotton. These values are based on air readings made between the hot-air and seed-cotton mixpoint and the entrance to tower drier.

Moisture content of seed cotton at the mixpoint averaged 11.7 percent for low air volume and 12.3 percent for the high air volume. Air volume had no significant effect on the moisture content of seed cotton at subsequent points in the

TABLE 1.—*Projected and actual air volumes and mixpoint temperatures*

Projected air volume and mixpoint temperature	Actual air volume (ft³/min)		Mixpoint temperature, average all treatments[1] (° F)
	No cotton in system[1]	Cotton in system[2]	
Air volume (ft³/min):			
3,500	3,600a	3,235a	.....
4,500	4,400b	3,900b	.....
Mixpoint temperature (°F):			
150	......	......	158a
200	......	......	209b
250	......	......	257c
300	......	......	309d
350	......	......	357e

[1] Means not followed by a common letter differ at a 1-percent level of significance.

[2] Means not followed by a common letter differ at a 5-percent level of significance.

TABLE 2.—*Air-volume/seed-cotton ratio for each test variable*

Projected air volume and mixpoint temperature	Seed-cotton processing rate[1] (lb/min)	Air volume[2] (ft³/min)	Air-volume/seed-cotton weight ratio[2] (ft³/min/lb)
Air volume (ft³/min):			
3,500	104	3,235a	31.1a
4,500	102	3,900b	38.3b
Mixpoint temperature (°F):			
150	100a	3,575	35.8
200	104b	3,585	34.5
250	103ab	3,600	35.0
300	104b	3,545	34.1
350	105b	3,535	33.7

[1] Means for mixpoint temperature not followed by a common letter differ at a 5-percent level of significance.

[2] Means for air volume not followed by a common letter differ at a 5-percent level of significance.

drying and seed-cotton-cleaning systems, or on the moisture content of lint (table 3).

Among the five temperature levels, the moisture content of seed cotton ranged from 11.8 to 12.3 percent at the mixpoint. Greatest decreases in moisture content were achieved at the highest temperature levels, although the moisture content of cotton at the entrance to the tower drier did not differ significantly among the five temperature levels. Decreases in seed-cotton moisture content between the mixpoint and the tower drier entrance were 0.6, 0.7, 1.0, 1.1, and 1.6 percentage points at temperatures of 150°, 200°, 250°, 300°, and 350° F, respectively. These reductions were achieved in a total distance of 25 feet. At the tower drier exit, moisture content of cottons processed at mixpoint temperatures of 150° and 200° F were significantly higher than that of cottons processed at temperatures of 300° and 350° F. Moisture content of cottons at the feeder apron were comparable to those at the tower drier exit for each temperature level. Moisture content of lint decreased as the temperature at the mixpoint was increased, and ranged from 6.5 to 4.4 percent.

Air volume did not significantly affect removal of moisture from seed cotton in the drying system, although trends did indicate greater removal with the higher air volume (table 4). At a given temperature and processing rate, the drying potential increases as the air volume increases. Greater moisture removal is therefore expected at higher air volumes.

Increasing the mixpoint temperature from 150° to 350° F resulted in increased moisture removal from seed cotton in the drying system. Moisture content decreased from 1.04 to 2.68 percentage points with the low air volume and from 1.24 to 2.85 percentage points with the high air volume.

One way to measure the efficiency of a drying system is to determine the weight of moisture removed per unit volume of air. For combined temperature levels, 0.55 pound of moisture was removed from seed cotton per 1,000 cubic feet of air when using low air volume as compared with 0.52 pound per 1,000 cubic feet when using high air volume (table 4).

The weight of moisture removed per 1,000 cubic feet of air increased as the mixpoint temperature was increased, ranging from 0.32 to 0.82 pound for combined air volumes. The effects of air volume and temperature on the removal of moisture from seed cotton in the drying system are graphically illustrated in figure 1.

After cotton was introduced into the system, approximately 5 to 7 minutes were required for temperatures to stabilize. Temperature drops were greatest between points closest to the mixpoint. For every mixpoint temperature level, temperatures at each point of measurement, excluding the mixpoint, were higher with the high

TABLE 3.—*Effects of air volume and mixpoint temperature on moisture content of seed cotton and lint*

Air volume, mixpoint temperature, crop year	Percent seed-cotton moisture at—				Lint moisture at lint slide[1] (percent)
	Hot-air and seed-cotton mixpoint	Entrance to tower drier	Exit of tower drier[1]	Feeder apron[2]	
Air volume (ft³/min):					
3,500	11.7	10.7	10.0	10.0	5.8
4,500	12.3	11.3	10.3	10.1	5.4
Mixpoint temperature (°F):					
150	11.8	11.2	10.7a	10.5a	6.5a
200	11.9	11.2	10.6a	10.5a	6.1ab
250	12.1	11.1	10.2ab	10.0ab	5.7b
300	11.9	10.8	9.7b	9.6b	5.0c
350	12.3	10.7	9.5b	9.7b	4.4d
Crop year:					
1st	12.3	11.4	10.5	10.3	5.1
2d	11.7	10.6	9.8	9.8	6.1

[1] Means for mixpoint temperature not followed by a common letter differ at a 1-percent level of significance.

[2] Means for mixpoint temperature not followed by a common letter differ at a 5-percent level of significance.

air volume than they were with the low air volume (table 5).

Thermocouples for measuring temperatures between shelves in the tower drier were located at the midpoint laterally. Temperatures between shelves 22 and 23 were higher than those between shelves 16 and 17 for all air volumes and mixpoint temperatures during the first

TABLE 4.—*Effects of air volume and mixpoint temperature on removal of moisture from seed cotton*[1]

Air volume, mixpoint temperature, crop year	Reduction in seed-cotton moisture at—					
	Low air volume		High air volume		Combined air volume	
	Percentage points	Lb/1,000 ft^3 air[2]	Percentage points	Lb/1,000 ft^3 air[2]	Percentage points[3]	Lb/1,000 ft^3 air[2]
Air volume (ft^3/min):						
3,500	1.72	0.55	....	....	1.72	0.55
4,500	....	....	1.98	0.52	1.98	.52
Mixpoint temperature (°F):						
150	1.04	.33	1.24	.31	1.14a	.32
200	1.02	.33	1.46	.38	1.24ab	.36
250	1.88	.60	1.87	.48	1.88bc	.54
300	1.97	.64	2.49	.66	2.23cd	.65
350	2.68	.88	2.85	.77	2.77d	.82
Crop year:						
1st	....	....	....	....	1.85	.55
2d	....	....	....	....	1.86	.52

[1] Moisture removed between mixpoint and tower drier exit.

[2] Data not analyzed statistically.

[3] Means for mixpoint temperature not followed by a common letter differ at a 1-percent level of significance.

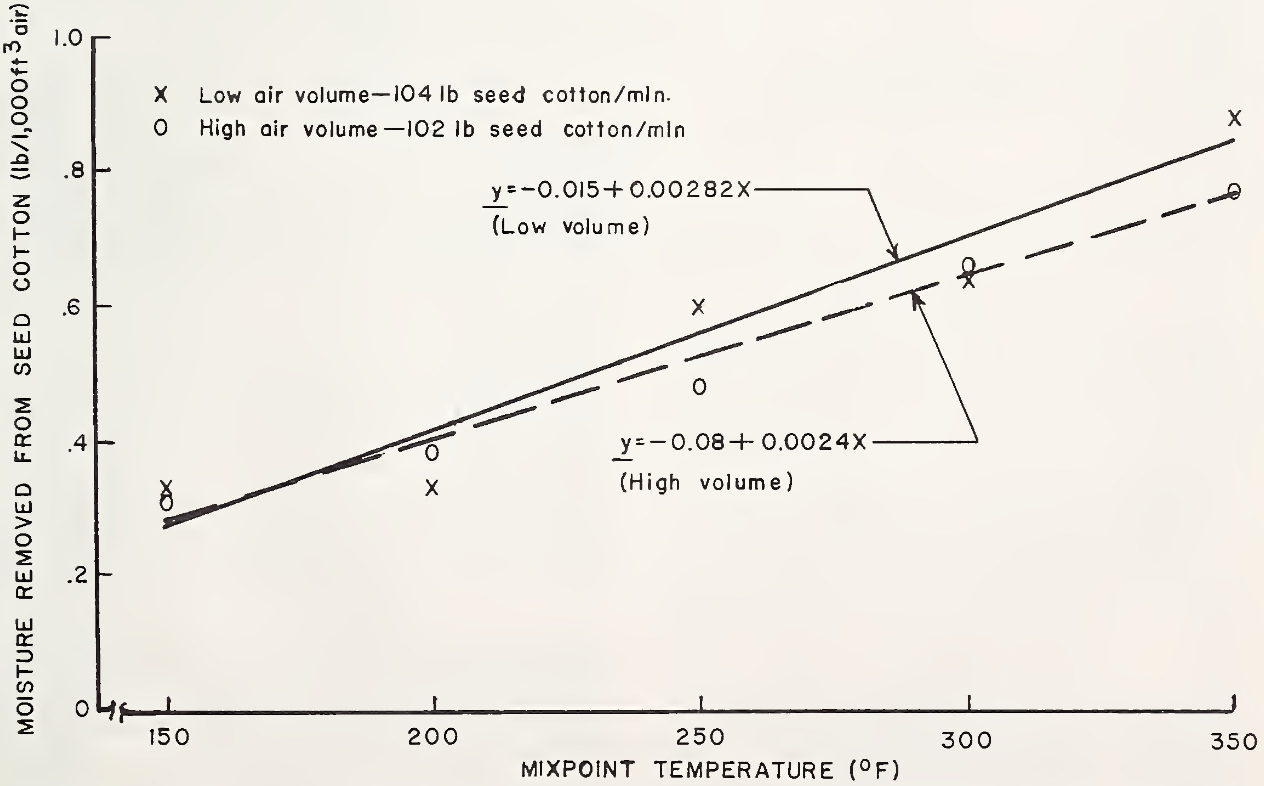

FIGURE 1.—Effects of air volume and temperature on removal of moisture from seed cotton in standard 24-shelf tower drier.

TABLE 5.—*Effects of air volume and mixpoint temperature on temperature at selected locations in conditioning system*

Air volume (ft^3/min)	Mixpoint temperature (°F)	Temperature (°F) at—					
		Mixpoint	Entrance to tower drier	Between shelves 10–11	Between shelves 16–17	Between shelves 22–23	Entrance to 7-cylinder cleaner No. 1
3,500	150	156	122	108	96	101	79
3,500	200	208	153	132	115	122	92
3,500	250	246	182	157	133	143	104
3,500	300	306	219	185	158	169	119
3,500	350	347	249	210	176	191	135
4,500	150	154	128	116	104	108	95
4,500	200	206	161	141	125	131	101
4,500	250	256	195	168	145	152	109
4,500	300	300	222	191	165	175	126
4,500	350	349	258	221	187	199	138

year. During the second year, additional thermocouples were placed at each side of the drier between shelves 16 and 17 and shelves 22 and 23. Between shelves 16 and 17, the highest temperature occurred at one side of the drier, and between shelves 22 and 23, the highest temperature occurred in the middle (table 6). However, the maximum temperature between shelves 22 and 23 exceeded the maximum temperature between shelves 16 and 17. These data indicate that airflow through the tower drier meanders from side to side and that there are significant differences in temperature across the width of a drier shelf. With balanced airflow, temperatures would normally decrease as air progressed through each shelf of the tower drier.

Trash levels in the seed cotton ranged from 5.6 to 6.2 percent, and trash levels of cotton processed at mixpoint temperatures of 150° and 200° F were significantly lower than those of cottons processed at 350° F. Though there were differences in source-cotton trash content among mixpoint temperatures, efficiency of seed-cotton cleaning system increased as the mixpoint temperature increased, ranging from 47.9 percent at a mixpoint temperature of 150° F to 59.1 percent at a temperature of 350° F (table 7).

The volume of air used in the drying system had no effect on classer's grade index, staple length, lint turnout, or lint value, and the classer's grade index was not affected by mixpoint temperature level. Moreover, two stages of saw-type lint cleaning apparently nullified differences in the trash level of cottons at the feeder apron attributed to drying system temperatures (table 8).

Temperature level did affect staple length, which generally decreased as the temperature level increased. Lint turnout also decreased as the mixpoint temperature was increased, ranging from 520 pounds of lint per 1,500 pounds of seed cotton at a mixpoint temperature of 150° F to 504 pounds at a mixpoint temperature of 350° F.

Lint value, based on Greenville, S.C., October 1971–72, spot market prices, decreased as the mixpoint temperature was increased, there being a $3.92 difference between the lint values of cotton processed at the two extreme temperature levels. Most of the difference was accounted for in the lint turnout, which is affected primarily by changes in moisture and trash levels. As the

TABLE 6.—*Temperature profile across selected shelves in tower drier*

Air volume (ft^3/min)	Mixpoint temperature (°F)	Temperature (°F) between shelves 16–17			Temperature (°F) between shelves 22–23		
		Left	Middle	Right	Left	Middle	Right
3,500	150	99	96	95	93	101	95
3,500	200	116	115	113	110	122	113
3,500	250	138	133	130	127	143	129
3,500	300	162	158	152	147	169	150
3,500	350	183	176	168	163	191	170
4,500	150	106	104	101	101	108	101
4,500	200	127	125	118	119	131	119
4,500	250	149	145	137	136	152	138
4,500	300	171	165	153	151	175	156
4,500	350	191	187	177	172	199	175

TABLE 7.—*Effects of air volume and mixpoint temperature on seed-cotton-cleaning system efficiency*

Air volume, mixpoint temperature, crop year	Seed cotton feed rate[1] (bales/hour)	Seed-cotton moisture at mixpoint (percent)	Seed-cotton trash content[1] (percent)	Seed-cotton-cleaning efficiency[2] (percent)
Air volume (ft^3/min):				
3,500	4.2	11.7	6.0	53.7
4,500	4.1	12.3	5.8	53.5
Mixpoint temperature (°F):				
150	4.0a	11.8	5.6a	47.9a
200	4.2b	11.9	5.7a	51.5ab
250	4.1ab	12.1	6.0ab	53.3ab
300	4.2b	11.9	5.9ab	56.1bc
350	4.2b	12.3	6.2b	59.1c
Crop year:				
1st	4.3	12.3	6.9	51.5
2d	4.0	11.7	4.9	55.7

[1] Means for mixpoint temperature not followed by a common letter differ at a 5-percent level of significance.

[2] Means for mixpoint temperature not followed by a common letter differ at a 1-percent level of significance.

mixpoint temperature increases, moisture content of seed cotton and lint decreases, which in turn increases the efficiency of seed-cotton and lint cleaning machinery in removing foreign matter.

Though not significant, lint value based on local Commodity Credit Corporation support prices followed the same trend.

CONCLUSIONS

Increasing the air-volume to seed-cotton weight ratio from 31.1 to 38.3 cubic feet per minute per pound of seed cotton had no significant effect on moisture removal from seed cotton in the drying system. Neither did air volume affect efficiency of the drying system, based on weight of moisture removed from seed cotton per 1,000 cubic feet of air. These limited data indicate that the air-handling system should be designed to provide only enough air to convey seed cotton through the drier without danger of chokage.

Moisture removed from seed cotton in the drying system increased as the mixpoint temperature was increased, regardless of air volume. The temperature drop between the air and cotton mixpoint and all other points in the drying system is greater at the lower air volume.

Studies should be continued to determine optimum combinations of air volume and mixpoint temperature for achieving maximum efficiency in the drying system.

TABLE 8.—*Effects of air volume and mixpoint temperature on classer's results, lint turnout, and lint value*

Air volume, mixpoint temperature, crop year	Classification		Lint turnout[2] (lb/1,500 lb seed cotton)	Lint value (dollars)[3]	
	Grade index[1]	Staple[2] (32ds inch)		Support price[4]	Spot market[2]
Air volume (ft^3/min):					
3,500	91.4	34.1	515	105.68	138.08
4,500	90.8	34.0	509	102.99	135.79
Mixpoint temperature (°F):					
150	90.6	34.2a	520a	105.83	139.24a
200	90.5	34.1ab	516ab	104.45	137.62ab
250	90.8	34.1ab	511bc	103.96	136.65b
300	91.8	33.8b	507cd	103.98	135.86b
350	91.8	34.0ab	504d	103.48	135.32b
Crop year:					
1st	87.7a	34.1	501	96.88a	138.86
2d	94.5b	33.9	523	111.79b	135.01

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[1] Code 31 (Middling White) = 100. Means for crop year not followed by a common letter differ at a 5-percent level of significance.

[2] Means for mixpoint temperature not followed by a common letter differ at a 1-percent level of significance.

[3] Values based on Commodity Credit Corporation support price, 1971–72, Pickens County, S.C., and spot market price, October 1971–72, Greenville, S.C.

[4] Means for crop year not followed by a common letter differ at a 5-percent level of significance.

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